WIRELESS GESTURE CONTROLLED WHEEL CHAIR USING IMAGE PROCESSING

ChaitrashreeV[1], Vivechana M. S[2], Anindita Das[3], Shewtha N. S[4], Shilpashree P. S.[5]
Department of Electronics and Communication,
Siddaganga Institute of Technology Tumakuru, Karnataka

Abstract

The differently abled and elderly people who are in need of a wheel chair are estimated to be over 100 million worldwide. The idea is to develop a gesture controlled wheel chair which can be navigated using hand gestures. The hand gestures are processed using Image processing algorithm which navigates the wheel chair to the desired destination. The hand gestures are captured using a camera mounted on the wheel chair. The gestures are processed in raspberry pi using Open CV platform. The gestures are then recognized and the DC motors which drive the wheel chair are controlled based on the gesture. By detecting the gesture, it is possible to move the wheel chair in specific direction such as forward, backward, left, right and halt. The proposed system works according to the user input i.e., if any two fingers are detected, the wheel chair will move towards forward direction. Similarly, the detection of any three fingers makes the wheel chair to move in backward direction. Wheel chair will move towards left, if any four fingers are detected. If any five fingers are detected, the wheel chair will move towards right direction and the wheel chair will stop, if no finger gestures are detected.

Keywords: Electroencephalograph (EEG), Convex hull, Raspberry Pi, Region of Interest (ROI).

I. Introduction

In today's time, an estimated one percent of the world's population needs a wheel chair. An increasing percentage of elderly and disabled people who want to improve their personal mobility, wheel chair is the best assistive device. A specially abled persons (usually the disability of the lower part of the body) can find it convenient to move around using the help of a wheel chair individually. This paper explains how to develop many of today's wheel chairs by applying slight design modifications to produce more durable and more comfortable wheel chairs for people who use them on a daily basis. The current wheel chairs are mostly button driven, and cannot fully meet the need of the disabled and elder people. Use of gesture controlled wheel chair is very much user friendly and requires very less muscle movement from the user. An associated algorithm is used to detect the finger movement through open CV using raspberry pi 3. The algorithm detects the convex hull to recognize the finger tips. Convex hull is the convex set enclosing the hand region. The system works on the ARM 8 Raspberry pi board to operate the wheel chair wirelessly according to input given through the Raspberry pi board. By detecting the finger gesture, it is possible to move the wheel chair using DC motor in specific direction like forward, backward, left, right direction.

System works according to the user input i.e., if two fingers are detected, the wheel chair will move towards left. If three fingers are detected, the wheel chair will move towards right. If four fingers are detected, wheel chair will move backward. If five fingers are detected the wheel chair will move in forward direction. This is totally depending on the software and hardware with the use of ARM 8 platform like raspberry pi and USB camera interface.

II. Literature survey

A. Joystick based wheel chair

Joystick based wheel chair uses joystick as the primary interface between the user and the wheel chair. Using joystick, one can manually control the wheel chair. The user has to press and hold the buttons provided on the joystick to move in the desired direction [1]. The disadvantage of this method is that the extensive or prolonged use of joystick may cause numbness or soreness in the hands and can make it uncomfortable for the user to use

B. EEG System based wheel chair

The Electroencephalograph (EEG) system consists of the gyroscope Emotive Excess post-exercise oxygen consumption (EPOC) headset in order to detect head movements. Emotive EPOC headset is a device that measures EEG activity from 14 saline electrodes is also proposed. These electrodes are arranged according to the 10/20 System [2]. The disadvantage of EEG system is that EEG signals are very weak (ranging from 1 to 100uv), hence signals may get corrupted

C. Voice Controlled wheel chair using MEMS

Voice Controlled wheel chair using accelerometer is also available for physically disabled people which uses voice recognition and Micro-Electro-Mechanical Systems (MEMS) motion sensor. A user dependent voice recognition system navigates the wheel chair. The wheel chair can be driven using voice commands [3]. The disadvantage is that the paralyzed person cannot operate efficiently using voice and also time required to acknowledge voice command is more.

Other existing systems:

Tremendous leaps have been made in the field of wheel chair technology. Some existing wheel chairs are fitted with pc for the gesture recognition. But making use of the pc along with the chair makes it bulkier and increases complexity as well as cost. They also limit the long range of communication. Various methods have been implemented for allowing physically challenged persons, including a Quadriplegic to control a motorized wheel chair.

III. Proposed work

The block diagram of wireless gesture controlled wheel chair is shown in Figure.1. The system works on the principle of finger gestures. The wheel chair has total of five motions namely forward, backward, left, right and halt.

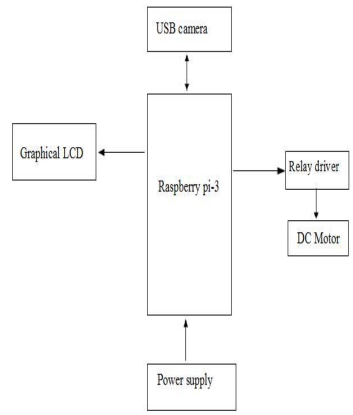

Figure.1: Block Diagram of Wireless gesture controlled Wheel chair.

The project is concerned with the implementation of finger gesture recognition technology (image processing) using raspberry pi board. Raspberry pi is credit card sized single board computer, in which camera and relay driver circuit are interfaced to it through USB ports available on the board. The camera is fixed on the frame of the wheelchair.

An image of the finger gestures are captured by the camera and that is considered as an input image. Then that image is sent to the raspberry pi board, where the processing of that image will be done. Then the output is sent to the relay driver circuit which enables the DC motor to rotate in accordance to desired direction (i.e., forward, backward, left, right and stop).

Gesture Identification Process:

The heart of the system is to detect the gesture through image processing. The gesture recognisation system uses an open CV software to detect the convexity of finger gestures. Steps for the finger recognisation is given below

1. Configure the open CV with python.
2. Image frames are captured by the USB camera and displayed.
3. Extract the ROI (Region of interest) from input frames.
4. Find out the contour and draw the convex hull.
5. Find the convexity defects. Depending upon the number of defects, recognizes the finger gesture.

Description of the Hardware components used in the system design:

Camera: A 720 pixels high definition USB camera is having an resolution of 1280 x 720 pixels. It has been used for better clarity of an image. Camera consists of lens and image sensor. It is connected to frame of the Wheel chair. The finger gesture is captured by the camera and that image is considered as an input image. It has a frame rate of 30 frames per second for fast image processing.

Raspberry pi: The Raspberry Pi-3 is a credit-card-sized single-board computer which is developed in the UK by the Raspberry Pi foundation. The Raspberry Pi [4,5] has a Broadcom system on a chip, which contain 256 mega bytes of RAM and it can be upgraded to 512 MB. It does not include a built-in hard disk or solid-state drive, but uses an SD card for booting and persistent storage. Raspberry Pi supports OS like Linux, Android, Linux and Unix.

DC motor: A DC motor is a device that converts electrical energy into mechanical energy. In any electric motor, operation is based on simple electromagnetism. A current carrying conductor generates a magnetic field, when it is placed in an external magnetic field. It will experience a force proportional to the current in the conductor and to the strength of the external magnetic field. A DC motor's speed can be controlled over a wide range, using either a variable voltage or by changing the strength of current in its field windings. DC motor used in the project is 30rpm.

Relay driver: Relay driver is an electromagnetic switch that opens and closes the circuits electromechanically or electronically. It is used to drive wide variety of loads and also used to interface relays with other circuitry. The relay contact is normally open, when the relay is not energized. When the relay is energized, the relay contact is closed. In either case, applying electrical current to the contacts will change their states. Relays are generally used to switch smaller currents in a control circuit. It does not usually control power consuming devices except small motors. Relays can control larger voltages and currents by having an amplifying effect. Protective relays can protect equipments from damage by detecting electrical abnormalities including overcurrent, undercurrent, overloads and reverse currents. In addition relays are also widely used to switch starting coils, heating elements, pilot lights and audible alarms

Graphical Display: The Graphical LCDs are used to display customized characters which are different from the ordinary character lcds like 16x1, 16x2, 16x4, 20x1 etc. An ordinary lcds can print only characters or custom made characters. They display characters in a fixed size matrix normally 5x7 or 5x8, whereas the graphical lcd have 128x64=8192 dots or 8192/8=1024 pixels (i.e., 128 columns and 64 rows). It can display character in fixed size and also can display the pictures.

Working: The camera is used to capture the input from the finger of the user. When the finger gesture is detected, then it is processed in raspberry pi board. The output of the pi is in binary format. Then it is fed to the relay driver circuit which enables the DC motor to move forward when 1010 is received. Similarly it will move backward when 0101 is received, rotate left when 1001 is received and rotate right when 0110 is received.

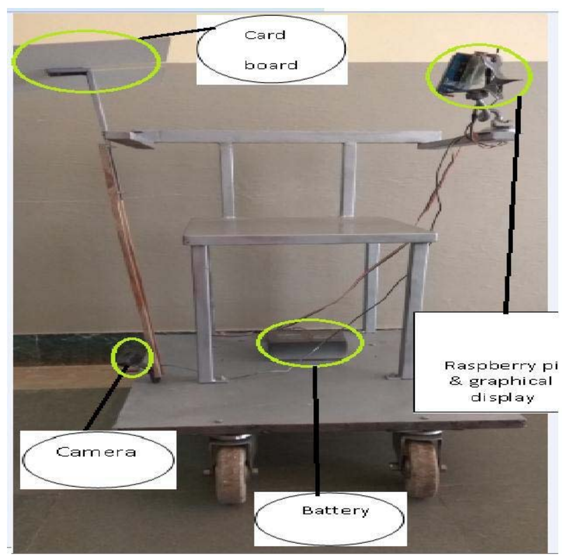

Figure.2: wheel chair model

The wheel chair model which consists of raspberry pi, graphical display and battery is shown in Figure.2. Two DC motors of 30rpm are fixed to the back wheels of the wheel chair. Freely movable Omni wheels are used as front wheels. The card board is fixed on the frame of the wheel chair for illumination purpose. LCD is used to display the finger gesture so that the user can visualize it.

The detailed explanation of the algorithms required to build the system and the flow chart which depicts the process flow is discussed.

Process Flow
There are two major parts in the flow of processes. The first part is to detect the finger gesture and the other part is to drive the motors. The flowchart of wireless gesture controlled wheelchair using image processing is shown in Figure.3. The process flow can be explained in the following steps:

1. Initialization

The serial communication set up is to be used for the interface between Open CV and the controller, then the video is captured by the USB camera.

2. Video Processing

The continuous video will be recorded. For accurate results, contrast stretching is performed on each frames to make the dark regions much darker and bright regions much brighter. This ensures better detection of the finger gestures.

3. Estimation

After performing pre-processing operations on each frame, the finger gestures are detected. It is done by estimating the fingers present with in the bounding box of width 100 pixel and height 300 pixel. Thus, a threshold is set and the fingers are detected which can be used for the further processing.

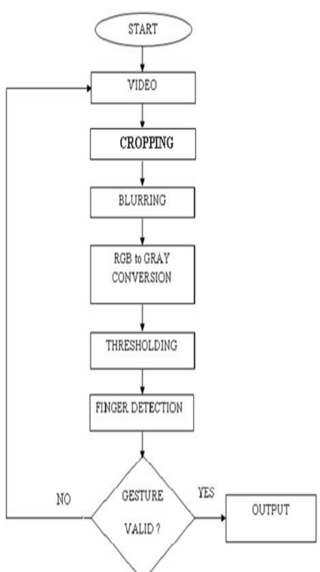

Figure.3. Flowchart of wireless gesture controlled wheelchair

Cropping
Cropping is the removal of the outer parts of an image to improve framing, accentuate subject matter or change aspect ratio. Here an original image which is shown in Figure.2: (a) is cropped and it is shown in Figure.4: (b). The size of the cropping is 100 pixel width and 300 pixel height.

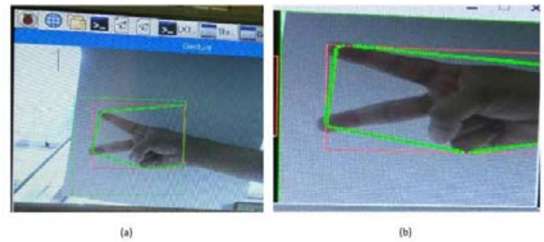

Figure.4: Image cropping: (a) Original image, (b) Cropped image.

RGB to gray
In RGB model, each color appears in its primary spectral components of red, green and blue. The colored image, which is in RGB format will be cropped and then converted into a gray scale image.

Blurring
Blurring means that each pixel in the source image gets spread over and mixed into surrounding pixels[6]. Another way to look at this is that each pixel in the destination image is made up out of a mixture of surrounding pixels from the source image. Blurring an image reduces the sharpening effect, this makes the detection more accurate.

Thresholding
Image frame is taken as input from the USB camera in the RGB format and the image is converted into gray scale. Then either a static threshold value is used or a threshold value is selected from 0 to 255 according to the user specification. The threshold value should be chosen by the user in such a way that the white blob of the hand is segmented with minimum noise possible. Hence the threshold value of 127 is chosen to get an exact value of an image.

Contour and convex hull
Contours are straight lines or curves describing the intersection of one or more horizontal planes with a real or hypothetical surface. It joins points above a given level and of equal elevation. A contour map illustrates the contour using contour

lines. When the lines are close together, the magnitude of the gradient is usually very large.

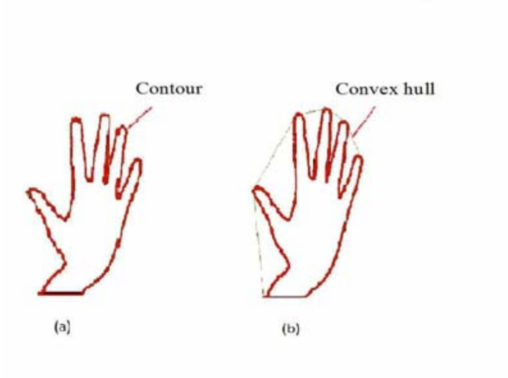

Figure.5. Contour and convex hull: (a) Contour, (b) Convex hull

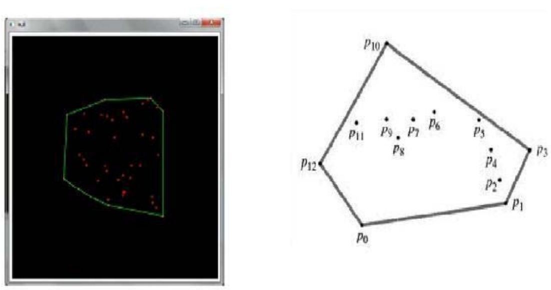

Figure.6. Convex hull

The convex hull is a set of points in the euclidean space. Convex hull point (Figure.6) is more likely to be on the fingers as they are extremities, therefore the finger will be detected. Detected contour and convex hull is shown in Figure.5.

Convexity Defects

When the convex hull is drawn around the contour of the hand, it fits the set of contour points of the hand within the hull. It uses minimum points to form the hull to include all contour points inside the hull and maintain the property of convexity. This causes the formation of defects in the convex hull with respect to the contour which is drawn on the hand.

A defect is present wherever the contour of the object is away from the convex hull drawn around the same contour. Convexity defect gives the set of values for every defect in the form of vector. The vector contains the start and end point of the line of defect in the convex hull. These points indicate indices of the coordinate points of the contour and can be easily retrieved by using start and end indices of the defect formed from the contour vector. Convexity defect [7] also includes index of the depth point in the contour and its depth value from the line. The areas between the fingers (all marked arrows) in the schematic of hand contour are the convexity defects as shown in Figure.7.

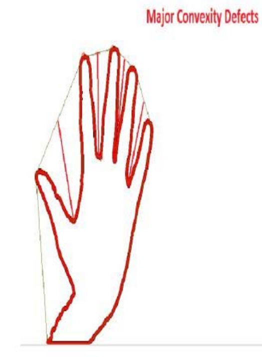

Figure.7. Convexity Defects

Finger Counting

In this method, it makes use of convexity defects for counting the number of fingers. The data structure of convexity defect gives the depth of the defects. Many such defects occur in a general hand image due to wrist position and orientation. There are many defects that are formed, but the depth of defect formed due to the gap between two fingers is much greater. For two adjacent fingers, there is one defect. If there is one finger or no finger in the image, then the technique fails since there is no large defects.

The Gesture is recognized by firstly taking the images from USB camera, which is in the form of videos because the frame rate of camera is 30 frames per second. These video files are opened for reading those frames and displaying the frame then convert that RGB images into the Gray scale images. Then reduce the high frequency noise using Gaussian blurring to make the contour detection process more accurate. For extracting the ROI the output is applied to the binary thresholding.

EXPERIMENTAL RESULTS

The number of fingers detected by the system corresponds to the movement of wheel chair in the required direction. A high definition USB camera of 1280 x 720 pixel resolution is used to capture the live video at a frame rate of 30 frames per second. It can adjust itself to the lighting variations. The rechargeable battery of 12V, 5A is used in the project. Once the battery is fully charged, it can drive the wheel chair continuously for 3 hours. Two DC motors each of 30 rpm are used. The weight of the wheel chair is 10kg with no load. The wheel chair can handle a maximum weight up to 70kg. The demonstration is done in MISSION10X lab of Electronics and Communication department in Siddaganga Institute of Technology. Here the computer table is used as a reference.

The wheel chair will move in forward direction(Figure.8 (c)), when any two fingers are detected which is displayed on lcd as shown in Figure.8: (a) and (b). The system is able to recognize any two fingers. Similarly, Figure.9 shows the detection of three fingers, then it is processed by the system and makes the wheel chair to move backward. Figure.10 depicts the detection of four fingers, then it is processed corresponds to the left turn of the wheel chair. Figure.11 depicts detection of five fingers, then it is processed corresponds to the right turn of the wheel chair. When no finger gesture is detected as shown in Figure.12, the wheel chair will halt.

Figure.8. Gesture of two fingers, wheel chair moves forward:

(a)LCD displaying the gesture of two fingers, (b) alternative finger gesture, (c) Wheel chair movement in forward direction

The system is tested on four users under different lighting conditions (day, night, dim light, no light) for 20 to 50 attempts. The number of successful attempts are noted against the total number of attempts and accuracy is computed for each user. The accuracy results after testing is found to be more than 90%.

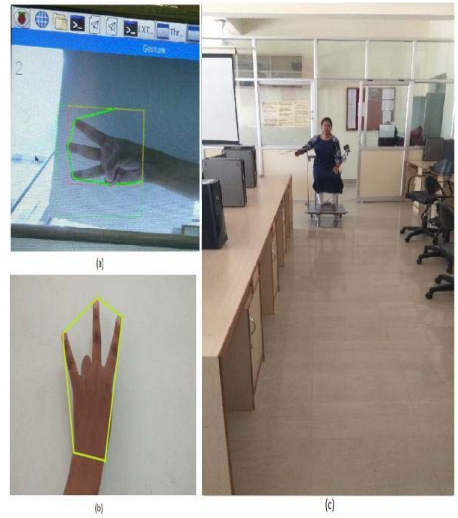

Figure.9. Gesture of three fingers, wheel chair moves backward: (a) LCD displaying the gesture of three fingers, (b) alternative finger gesture, (c) Wheel chair movement in backward direction.

Figure.10. Gesture of four fingers, wheel chair turns left: (a) LCD displaying the gesture of four fingers, (b) alternative finger gesture, (c) Wheel chair turning towards left

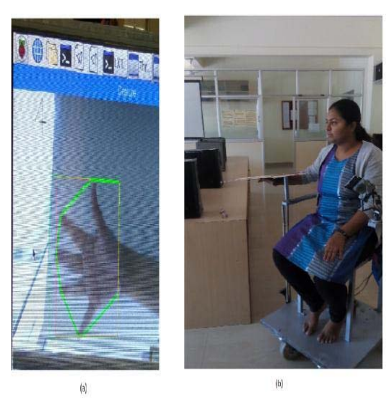

Figure.11. Gesture of five fingers, wheel chair turns right: (a) LCD displaying the gesture of five fingers, (b) Wheel chair turning towards right

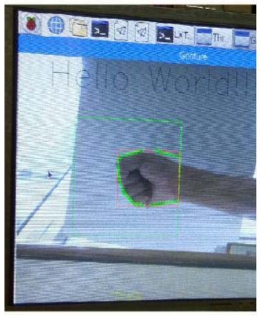

Figure.12. Gesture of no finger, wheel chair halt.

IV. CONCLUSION

A model of the wheel chair that navigates based on the finger gestures is designed, developed and tested, which helps the specially abled persons with limited or no limb movement. The gesture identification is done by using image processing. Using this technique it is possible to control the wheel chair and manoeuvre it based on the gestures identified. Compact size of Raspberry Pi, usage of image processing and avoiding the usage of laptop/notebook pc is an added advantage to this technique. The system functions with an accuracy of more than 90% in addition to the above mentioned advantage.

REFERENCES

[1] Fahad Wallam, Muhammad Asif, "Dynamic finger movement tracking and voice commands based smart wheel chair" International Journal of Computer and Electrical Engineering, August 2011.

[2] Ericka Janet Rechy-Ramirez, Huosheng Hu and Klaus McDonald-Maier "Head movements based control of an intelligent wheel chair in an indoor environment" Proceedings of the 2012 IEEE, International Conference on Robotics and Biomometics, December 11-14,2012, Guang-zhou, China, 978-1-4673-2126-6/12.

[3] Rahul C. M., Nalini C. Iyer "Accelerometer and voice controlled wheel chair" Proceedings of 4th SARC International Conference, 30th March-2014, Nagpur, India, and ISBN: 978-93-82702-70-2.

[4] Matt Richardson and Shawn Wallace, "Getting Started with Raspberry Pi", O'Reilly Media Inc. Publication, First Edition, December 2012.

[5]Resources and Support, https://www .raspberrypi.org/forums

[6] Gonzalez, Rafael C. and Woods, Richard E. 2002. Digital Image Processing, second edition Prentice-Hall Pearson.

[7] Amiraj Dhawan, Vipul Honrao, "Implementation of Hand Detection based Techniques for Human Computer Interaction", International Journal of Computer Applications (0975 8887), Volume 72 No.17, June 2013.